TROPICAL AGRICULTURE

THE OFFICIAL JOURNAL OF THE
IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

VOL. XVII, No. 2. FEBRUARY, 1940. PRICE 6d.

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THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, TRINIDAD, B.W.I.

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TRAINING AND RESEARCH IN SUGAR TECHNOLOGY.

THE Imperial College of Tropical Agriculture is fortunate in having a Department of Sugar Technology which is exceptionally well equipped for both training and research. The Department has been training sugar technologists since 1925 and its reputation as a sugar school is now firmly established. Most of its past students hold responsible posts chiefly in West Indian sugar concerns, and in recent years the demand for men which it has trained has been increasing rapidly. The Department has also done excellent research, and with the additional financial support generously contributed recently by leading British West Indian sugar companies it has been possible not only to strengthen the staff of the Department but also to extend its activities in several directions. A general account of its work may, therefore, be of interest to our readers.

The primary function of the Department is to provide specialised training in sugar technology. For this purpose it is equipped with an experimental and instructional factory. Most of the machinery for this factory was generously donated by members of the British Sugar Manufacturers' Association. The factory, though small, is complete in every way for making sugar of various grades. Its capacity is such that the 11-roller 10 ins. by 20 ins. milling plant grinds 3 tons of cane per hour with a pol extraction for the 1939 crop of 90.96. In spite of losses resulting from 12 hourly operation and from experimental work which was carried out, the recovery for 1939 was 10.26 tons cane per ton sugar. The factory thus is not a toy, but carries out operations on a scale comparable to a commercial factory. The benefits from the student's point of view of having such a factory attached to the Department are obvious.

The course offered by the Department has been mainly designed to produce cane sugar factory chemists. It covers a period of four years. During the first two years the student is given a thorough preliminary grounding in general agriculture and related subjects. This is followed in the third and fourth years by specialized instruction, both practical and theoretical, in all phases of sugar manufacture. To facilitate arrangements for practical training, lectures during the third and fourth years are restricted to the first four months of the session. The lectures

during the third year cover the manufacture of 96° sugar; the subjects include juice extraction, steam generation, boiling house procedure, field and factory control and practical sugar analysis. Throughout, the chemical aspect is stressed much more than the engineering and in this respect the course differs somewhat from those at most other sugar schools. The importance of some training in engineering has, however, been recognised. It is highly desirable that the chemical technologist should be capable of understanding the engineer's point of view and of discussing factory problems with him in his own language. Accordingly, an elementary course in engineering, covering such matters as factory fittings, belts and pulleys, steam engines and pumps is included in the curriculum.

When the courses of lectures are completed third year students work for one week at each of four or five of the large commercial sugar factories which co-operate in the scheme. Besides these visits, there is the operation of the College Experimental Factory for a period of five or six weeks. During this period a comprehensive system of control data and sampling is maintained, in which every student in turn collects samples, performs analyses and calculates results. Each student also works for a time as a junior shift chemist, and not only takes part in the operation of the factory, but also takes charge in turn of each of the different factory stations. The practical training in the third year thus covers a period of twelve to fourteen weeks and extends until shortly before the examinations begin. On the successful termination of his studies a student at the end of his third year is awarded the Diploma which, while not being considered a full professional qualification, would enable a man to take a junior post in a factory.

All students, however, are urged to proceed to the fourth year in order to take the Associateship of the College. The fourth year courses naturally cover more advanced ground than the third and, in addition, the student associates himself intimately with the departmental research work. Part of the requirements for the Associateship is the presentation of a dissertation bearing on the research. Only four courses of lectures comprising direct consumption sugars, utilization of by-products, refining (both char and carbon) and heat economy are given, during the first term of the session. The student has ample time for the preliminary laboratory work connected with his piece of research. During the crop period, the fourth year student mainly collects factory data to be incorporated in his dissertation and takes a responsible part in the operation of the experimental sugar factory. The work for his dissertation, which is carried out in the experimental factory often entails amplification by further work in the commercial factories. The local sugar companies, and particularly the contributors to the funds of the Department, give all help possible in throwing open their factories for investigational purposes. This is of very great benefit to the students, since problems of direct practical interest are under constant discussion and investigation.

It will be seen that the last two years of training are both highly intensive and extremely practical. The graduate is indeed competent the day he leaves the College to assume immediately the full chemical control and operation of a sugar factory and research pertaining thereto. In fact, many past students have done so very successfully. Such intensive training could not be given to large classes. Theoretically, the courses, students' laboratories and equipment are designed for classes of about six in each year. But actually the classes generally number only three or four, so that the teaching becomes practically of an individual nature. This applies not only to the lecture room but also to the factory. The standard of training aimed at is of a very high order. The extent to which the objective is attained is shown by the fact that graduates are achieving success throughout the British West Indian industry and that there are now more applications from employers for trained men than there are men in the class which will qualify in June this year.

As regards recent research an attempt to find a substitute for stannous chloride in the production of yellow crystal sugar has resulted in a highly interesting investigation into the factors controlling the colour reactions during process. A substitute for stannous chloride has been found to which there can be no objection on health grounds. A second process has also been evolved as a direct result of the colour investigation. On the suggestion of the manager of a local factory, an imbibition experiment was carried out which it is hoped will be the first of a series. The results show conclusively that under the conditions of the experiment, application of the imbibition fluids at the crack of the bagasse blanket is of less value than applying them as soon as possible on the intermediate carrier. The raw sugar clarification work, described in a paper read by the sugar technologist before the International Society of Sugar Cane Technologists' Congress in Louisiana in 1938, has been continued and both phosphate and silica are receiving attention. It is felt that there is still a considerable amount to be learnt from the practical point of view about these two important juice constituents. The importance of accurate milling control has been stressed by papers issued from the Department from time to time. Further data are being collected. For the past few years, work on the exhaustion of final molasses has given way to the more immediate problems of clarification. This was recommenced in 1939 but the results are not yet available.

The research work for the coming crop of 1940 has been planned and some of the preliminary laboratory work is still in progress. It was thought desirable that an opinion on the proposed programme should be obtained from some of the local sugar factories which contribute to College

funds. Accordingly, a meeting was recently arranged at the College. At this meeting which was well attended by sugar technologists employed by the Trinidad factories, the research programme was freely discussed. This led to some slight modifications and the incorporation of some valuable suggestions. It was regretted that it was not possible to invite representatives from all the West Indian sugar factories, but this may come about in future years. If such a meeting could be held every year or even every other year it would be most valuable in enabling the sugar technologist to direct his research upon the problems which are of most importance to most factories. In the meantime he will try to obtain such guidance, so far as he can, in respect of West Indian factories outside Trinidad, by visiting them when he is able to do so. But considerations of time as well as expense will prohibit frequent visits to any particular colony.

COLCHICINE TREATMENT AS A MEANS OF INDUCING POLYPLOIDY IN COTTON.

By S. G. Stephens.
(*Cotton Research Station, Trinidad, B.W.I.*)

During the last two years much attention has been paid to the effect of various alkaloids and growth substances on the cytological mechanism of plants (Blakeslee *et al*, Nebel and Ruttle, Levan, Kostoff, &c.). Levan (1938) has shown that the alkaloid colchicine has a specific effect on root divisions in Allium ; temporary inhibition of spindle formation during mitosis delays separation of the divided chromosomes and thus leads to the formation of polyploid cells.

The possibility of inducing polyploidy in cotton is of particular interest. The production of amphidiploids from sterile species hybrids might provide further evidence regarding Skovsted's (1934) theory that New World (n=26) cottons are amphidiploids ; thirteen chromosomes being homologous with Asiatic (n=13), and the remaining thirteen with wild New World (n=13) chromosomes. Induced polyploidy also offers possibilities of breaking down fertility barriers between species, and perhaps of extending the range of variability available to plant breeder and geneticist.

The optimum concentration of colchicine and method of treating the plant may vary considerably in different genera (Blakeslee and Avery 1937, Levan 1939, Rasmusson and Levan 1939). Experiments to determine the range of effective treatments for inducing polyploidy in cotton were started at the Cotton Research Station, Trinidad, in 1938 by H. B. Newcombe.

This preliminary work has now been expanded and the results are reported here.

The material studied has been chiefly St. Vincent Sea Island Superfine, V135 (*G. barbadense*, n=26) and N14 (*G. arboreum* v. *neglectum*, n=13). Plants which survived treatment were examined for abnormal vegetative characters, and at flowering their pollen was measured using an eyepiece micrometer. Only those plants with abnormal vegetative characters and with pollen of larger size than that found in control plants were retained. They were selfed and root tip chromosome counts were made of a representative number of the progeny plants obtained. Later it was found possible to distinguish diploid from tetraploid plants in these progenies by leaf characters alone, as early as the second leaf stage.

The following methods of colchicine treatment have been tried :—

(1) *Treatment of newly germinated seeds.*

On the second day after germination seeds were immersed from 1-4 days in aqueous solutions of colchicine ranging from 0.0125 per cent. to 0.4 per cent. The seedlings were then washed and planted out in 3 inch pots.

Result :

*V*135 : Out of 98 seedlings treated only 8 survived past the cotyledon stage. One of these later developed into a normal diploid. The other seven remained quite sterile over a period of 14 months. They flowered occasionally but the pollen was empty.

*N*14 : Out of 218 seedlings treated only 21 survived past the cotyledon stage. Eight of these were normal and three reverted to normal later. The remainder were abnormal sterile forms with the exception of 3 plants which gave tetraploid (n=26) progenies. These resulted from treatments of 0.025 % colchicine for 1, 1, and 2 days respectively.

(2) *Treatment of plumules in the cotyledon stage.*

Drops of colchicine were applied with a small brush to the plumule just as the first foliage leaf was on the point of unfolding. Drops were applied singly, allowing time to dry between each drop. (Range : 10-25 drops of 0.5 % to 4.0 % colchicine.)

Result :

*V*135 : Out of 64 plants treated only 5 died, these occurring in the higher concentration treatments (2.0 % and 4.0 %). Of the remainder, 24 plants reverted to normal. Only 5 progenies have so far been obtained, all having the normal (n=26) chromosome complement.

*N*14 : The results are summarised in Table I. It can be seen that there is a considerable range under which treatment is effective. The optimum concentration appears to be between 0.5 % and 1.0 %. A comparison between the proportion of plants killed in N14 with those killed in V135 suggests that higher concentrations might be more effective in the latter, since effective treatments are apparently sub-lethal.

Table I.

EFFECT OF COLCHICINE TREATMENT ON N 14.

TREATMENT.		BEHAVIOUR OF TREATED PLANTS.				COMPOSITION OF PROGENIES.			
Per cent. Colchicine.	No. of drops.	No. of plants treated.	No. of plants killed.	No. of plants reverting to normal.	No. of plants giving progenies.	No. of progenies examined.	Normal plants.	Tetra-ploid plants.	Per cent. tetra-ploids produced.
0.5	10	4	3	1	...	...	...	...	...
0.5	15	4	0	1	3	7	28	14	34
0.5	20	4	2	0	2	5	0	16	100
0.5	25	4	3	0	1	7	63	0	0
1.0	10	4	3	0	1	3	8	11	58
1.0	15	4	3	0	1	5	31	3	9
1.0	20	4	3	0	1	5	44	0	0
1.0	25	4	4	...	...	...	...	...	...
2.0	10	4	4	...	...	...	...	...	...
2.0	15	4	3	0	1	1	0	2	100
2.0	20	4	3	0	1	8	48	0	0
2.0	25	4	4	...	...	...	...	...	...
4.0	10	4	4	...	...	...	...	...	...
4.0	15	4	4	...	...	...	...	...	...
4.0	20	4	4	...	...	...	...	...	...
4.0	25	4	4	...	...	...	...	...	...
Total ...	...	64	51	2	11	41	222	46	...

(3) *Treatment of apical bud of main stem.*

Treatment was delayed until sympodia were formed. All lateral buds below the sympodial region were then excised, and drops of colchicine applied to the tip of the main axis. Ten drops of 0.5 % to 1.0 % colchicine were applied.

Result:

This was unsuccessful. Growth was checked and abnormal tissue produced, but no fertile flowers were formed until normality was regained. This happened rapidly in all surviving plants. More recent work with higher concentrations (1.0 % to 4.0 %) on sterile species hybrids suggests that treatment of the mature plant is ineffective.

(4) *Treatment of flower buds.*

Five to ten drops of 0.5 % to 1.0 % colchicine were applied to young flower buds of about 2 mm. in diameter (*i.e.* at approximately the stage corresponding with meiotic divisions of the pollen mother cells).

Result:

All surviving buds were normal.

(5) *Treatment of young bolls.*

Ten drops of 0.5 % to 4.0 % colchicine were applied, 1-2 days after pollination.

Result:

The treatment was only carried out on N14. In most cases the bolls fell off after a few days, or split prematurely owing to irregular carpel growth—the seeds were then found to be immature. Out of 114 bolls treated only 27 survived long enough to mature seed. So far no polyploids have been found in the progenies examined, although many of the seedlings showed effect of treatment (malformed leaves) in the early stages. No bolls survived at the highest concentration level, 4.0 %.

Discussion.

So far the only success has been obtained in N14. Tetraploids have been obtained in this species by treatments (1) and (2). Of these successful treatments, the latter appears to be the more convenient. It has the advantage that root growth is not checked by treatment, as is the case when the seeds are immersed in the solutions, and also it is economical both in colchicine and in the labour involved. Treatment 2 is now being applied to sterile species hybrids in the hope of producing amphidiploids. One, a hexaploid (n=39) has already been obtained from the sterile hybrid *G. barbadense* × *G. Raimondii*.

As expected, the tetraploid N14 plants, being auto-tetraploids had a certain amount of empty pollen. The viable grains had a mean diameter of 111.26 ± 0.08μ, as compared with a mean of 90.91±0.04μ in diploid N14 and 110.39 ± 0.20μ in V135, grown under similar conditions. The tetraploid had broader leaves and coarser stem hairs than the diploid; the lint hairs were 3 to 5 mm. longer but fewer per seed. Seeds were markedly bigger.

The tetraploid crosses freely with Upland and Sea Island cottons, but the hybrids though vigorous have so far proved sterile (cf. Skovsted, 1934).

An as yet unexplained feature is that the typical rough and distorted leaves resulting immediately from colchicine treatment and attributed by previous workers to mixoploidy are not confined to the actual treated plants but recur to a modified extent in all tetraploid, and in several diploid progenies. In both, the distortion decreases with increasing age of plant; the apparent recovery being greater in the diploids than in the tetraploids. The distortion appears again in several plants of the following generation (*i.e.* two generations removed from the colchicine treated plants). No tetraploid plant has so far been obtained which has leaves free from distortion prior to the flowering stage. Obviously mixoploidy cannot account for progeny abnormalities, and it is unlikely that environmental conditions can be entirely responsible, since control N14 plants growing under similar conditions show no sign of abnormality.

The experiments described above have been carried out under the direction of Mr. J. B. Hutchinson whom I wish also to thank for advice on the preparation of this article.

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FIELD EXPERIMENTS ON SUGAR CANE IN TRINIDAD.

Annual Report for 1939 by P. E. Turner, Sugar Agronomist to Department of Agriculture and Sugar Cane Investigation Committee of Trinidad.*

In this report are described the results of the field experiments on sugar cane harvested in Trinidad in 1939. Data for experiments reaped in previous years are also included provided these experiments were reaped again in 1939. The soil types on which the experiments are laid down are recorded.

The experimental scheme on sugar cane in Trinidad was begun with a single manurial experiment in 1927. Between 1928 and 1936 the scheme was gradually expanded to embrace as many agricultural operations as possible, *i.e.* drainage, cultural, varietal and other trials were included. Since 1936 the number of experiments has remained approximately stationary with an average of 65 a year. Layouts enabling orthodox use of the Analysis of Variance have invariably been used. Whenever possible the number of treatment replicates in each experiment has been large to give the maximum degree of quantitative precision to the data obtained. The scheme has been operated throughout under the auspices of the Sugar Cane Investigation Committee of Trinidad.

* Copies of this Report may be obtained on application to the Author, Sugar Cane Investigation Committee, Department of Agriculture, St. Clair, Port-of-Spain, Trinidad, B.W.I.

The report is divided into nine sections (1) Ground Limestone, (2) Sulphate of Ammonia, (3) Potash, (4) Phosphate, (5) Mixed Manures, (6) By-products as Manures, (7) Cultural Methods, (8) Planting Methods and (9) Varieties. In each section the effects of the various treatments or varieties on yield of cane, on quality of the crop and on yield of sugar are fully considered. In the liming, potash and phosphate sections the lime requirement or content of exchangeable potash or available phosphate of the soil of each experimental area is recorded. At the end of the report the general conclusions to which the experiments give rise are summarised with special reference to soil type. There are two appendices, of which one deals with the changes in the variety situation on sugar estates in Trinidad during 1935-39 and the other with rainfall data.

The report is clearly and carefully written. It comprises 262 pages. A brief review cannot do justice to the store of quantitative information it contains. Qualitative mention of only a few of the problems under critical investigation is possible.

The manurial and other sections are of interest in that they establish the necessity for the investigation of interactions (the influence of

one or more treatments on the effects of another), particularly as it is generally believed adequate for practical purposes to measure only direct effects.

In the section on liming a single dressing of finely divided limestone, equal to the lime requirement of the soil, has been shown to give large gains in yield over six successive crops. There are no indications that the beneficial effects of the dressing have begun to diminish with time. Less satisfactory results are recorded for the continued effects of a coarser grade of limestone. It is confirmed that liming can have a decided adverse effect on crop quality which nevertheless is unimportant in comparison with gain in yield of cane. It is shown that treatment with sulphate of ammonia can seriously diminish the gain in yield of cane and sugar from liming (and *vice versa*) and that the diminution in gain increases with size of dressing of nitrogen. Treatment with potash is found to be essential to obtain maximum gain in yield from liming (and *vice versa*) on potash-deficient soil.

The effects of annual dressings of sulphate of ammonia have been measured over seven successive crops on a very acid, humus-deficient clay which has never received organic manure. Each crop was burnt before harvesting. The gains in yield of cane and sugar per crop are large and there are no signs that the beneficial effects of the manure are lessening as a result of its continued application. Similar results have been obtained with heavier dressings of sulphate of ammonia on another area. Information is recorded concerning the optimum total dressing and time of application of sulphate of ammonia for a number of soil types. Treatment with other manures is shown to be necessary on certain soils to ensure maximum gain from nitrogen.

Treatment of each successive crop with potash is found necessary on potash-deficient areas to obtain maximum yield of cane and quality of crop. On one soil type the gain from potash has been shown to increase from one to ten tons of cane to the acre over six successive crops. Data are quoted which establish the importance of the effects of size of dressing of lime and of nitrogen on the gain to which potash can give rise. In certain circumstances small dressings of phosphate are shown to increase, and larger dressings to decrease, the gain from potash. As a result of experiments reaped during the past six years it has been possible to relate the soil content of exchangeable potash with response in yield of cane and sugar to size of dressing of potash. The manurial programmes with potash of sugar estates in Trinidad are now based on the results of field-to-field soil analyses.

On one soil type containing 22-24 p.p.m. of available P_2O_5 (Truog) small dressings of superphosphate have been found beneficial to plant and ratoon cane. Phosphate increased the yield of only the first of four successive crops on a second type. It was found of value only when the crop was damaged by froghopper blight on a third soil type. In general, however, the data show that response to phosphate is largely determined by size of dressing of applied lime, nitrogen and potash.

Effects on yield of such by-products of the sugar industry as pen manure, molasses and filter-press mud are recorded. The trend of the data throughout this report, and the earlier annual reports of the author, supports the conclusion that organic manure is not essential in the husbandry of sugar cane provided that inorganic manure is used with understanding.

In the sections on cultural and planting methods there are included experiments on drainage, furrowing, mulching, tillage and the spacing of plants. It is shown that excessive deepening of the drains between the cane beds can have an adverse effect on crop quality, and that mulching with megasse can give rise to satisfactory gains in yield if the mulch is applied at a suitable time and if appropriate use is made of inorganic manure. A large gain is recorded on one soil type as a result of closer spacing.

Experiments with varieties introduced from Barbados and elsewhere take an important place in the report. The variety Co.213 is shown superior to the standard variety Uba on an extensive soil type. Evidence is being accumulated of a close relationship between class of variety (hardy, hardy by noble and noble) and type of soil. For example the variety B.3439 is giving promise on soils of intermediate fertility and impeded drainage, and P.R.803 on soils of high fertility and good drainage.

During the period 1935-39 the proportion of estate areas in Trinidad (for which detailed returns are available) under noble canes has increased from 53.8 to 64.2 per cent. This progress has been due to improvements in agricultural methods for which the field experiments have been responsible in no small measure.

The report is worthy of detailed study by sugar-cane planters and by officers responsible for the conduct of experimental schemes in the field.

RIPENING OF COFFEE.

The time taken between blooming and ripening for various coffee varieties has been studied in Java. Thus robusta and its related forms require 318 days, conuga 313, liberica-arabica hybrids 306, and robusta-excelsa hybrids 357. Flowering from all varieties is, of course, not simultaneous but as a general rule it can be laid down that the varieties requiring the shortest time for development will be first ready for picking, provided they have a clearly defined flowering peak period. In interclonal planting for cross-pollination it is obviously advantageous to group together clones which as well as flowering will also ripen simultaneously. In hybrids, length of ripening period appears to be a character acquired exclusively through the female parent.—(*Horticultural Abstracts*, Vol. VIII, Abs. 1208.)

CACAO DIE-BACK.*

By O. J. Voelcker and J. West.
(*Department of Agriculture, Nigeria.*)

Introduction.

The occurrence of cacao die-back is a matter of considerable concern to the industry in the Gold Coast and in Nigeria. There is little doubt but that the cacao farmers in both colonies recognize a definite time limit to the economic life of their farms. The stage has not yet been reached, however, when this is reflected in diminishing total exports because the planting of new areas has been and is still proceeding with vigour.

The following report was presented to the Departments of Agriculture of the two colonies after a short tour through the Gold Coast, which we undertook, with the object of becoming acquainted with the conditions which exist throughout the cacao belt. In Nigeria these conditions are at their worst during the latter part of the dry season, which commences at the end of November and continues into March. We purposely visited the Gold Coast during February so as to see the cacao under conditions the least favourable for its growth. We think that this report may be of some general interest to other cacao growing countries, and our thanks are due to the respective Departments of Agriculture for permission to publish.

Reasons for Visit.

In Dade's report on swollen shoot of cacao (1), great prominence is given to the die-back and the dying out of cacao over extensive areas in the Gold Coast. It seemed most desirable to see the conditions under which this is occurring and to judge how far the control measures being adopted would be applicable in Nigeria. Visits of such a nature were recommended by Sir Frank Stockdale (2), an opinion which was unanimously endorsed at the Third West African Agricultural Conference (3), held in Nigeria in 1938.

We are very deeply indebted to Mr. A. C. Miles, Deputy Director, and to the Officers of his Department for the facilities so readily afforded to us and for the helpful interest taken in our visit.

Swollen Shoot.

This unique condition in cacao has not yet been recorded in Nigeria and it is apparently confined within a limited area only in the Gold Coast. In his report Date states (*loc. cit.*) :—

(i) "*Swollen Shoot.* The swollen shoot phenomena are new to science. They appear to indicate a systemic affection the etiology of which is not yet clear. The evidence, however, points to a physiological, and not a parasitic, diagnosis."

(ii) "*The Main Problem.* I am satisfied, however, that the extensive loss of trees is mainly, if not entirely, due to drought die-back, the result of environmental conditions which have been rapidly growing worse for many years; and that swollen shoot is a secondary affection of minor, if indeed of any, significance."

Our observations led us to agree with Dade that Swollen Shoot, whilst it presents a novel problem whose early solution is highly desirable, is only an incident in the general problem of cacao die-back.

Theories on Cacao Die-back.

Die-back is a condition which is found in nearly every country where cacao is grown. It represents a problem about which most people interested in this crop have produced theories, unsupported by experimental evidence, and we do not apologize for introducing our own theories in this report.

Briton-Jones (4) defined cacao die-back as a debility disease in which fungi play a secondary rôle, and he added that the symptoms depend upon the nature of the factor or factors which have caused a set-back in the growth of the plant. Amongst the primary factors he included drought, water-logging, poverty of the soil and "exposure."

To obtain a general perspective of the problem of cacao die-back, we give a summary of the theories which pertain in some of the cacao growing countries.

Trinidad.

In the Sangre Grande district, where there is a heavy rainfall and a permanently high water table in the soil, die-back is severe in cacao growing under heavy Immortel shade. In this case a lack of drainage is held to be the primary factor inducing die-back. Shephard (5) recognizes a die-back due to poor soils in certain parts of the island and advises the abandonment of cacao cultivation where such conditions exist.

Grenada.

The *Theobroma leiocarpa* of West Africa is the variety of cacao most generally grown in Grenada. The plantations have no overhead shade, but the soil round the trees is periodically given a dressing of pen manure and a deep forking. When die-back occurs, the symptoms are similar to those which appear in the drier cacao areas of Nigeria. The cause is held to be a lack of pen manure and forking, and it is claimed that die-back symptoms disappear as soon as these deficiencies are made good.

* Report on a visit to the Gold Coast.

Gold Coast.

Dade (*loc. cit.*) holds that drought is the fundamental cause of die-back throughout the Gold Coast. His theory is based upon the following points taken from his report :—

(i) That drought die-back is well known in all cacao producing countries (para. 21).

(ii) That in its natural habitat cacao grows in the dense shade of rain forest in conditions of steady high humidity (para. 22).

(iii) That in the Gold Coast critically dangerous climatic conditions prevail during the dry season, lasting for some months (para. 23).

(iv) That significant examples of the value of shade in the swollen shoot area are to be seen, as for example the case of individual cacao trees growing in excellent condition under the dense shade of mango trees (para. 26).

(v) That cacao has always been established in good forest conditions, but that, in the older districts, the shade trees have largely disappeared (para. 27).

(vi) That the existence, in the older areas, of dead cacao trees standing in thick grass shows how far desiccation has proceeded (para. 28-35).

(vii) That consequently the problem is one of drought die-back caused by exposure (para. 40).

Dade quotes extracts (page 12) from one of his articles published in 1927, from which the following two relevant paragraphs are taken :—

"In the Gold Coast the principal adverse factor which occurs, and which cannot be controlled, is the very well-marked dry harmattan season, which lasts for about three months. This alone excludes many otherwise suitable areas from cacao cultivation, or alternatively necessitates an artificial adjustment of conditions."

"In all parts of the cacao areas the effects of the harmattan and deforestation are evident, and in many districts it is becoming exceedingly difficult or even impossible to fill vacancies".

As a result of his observations and of shade experiments carried out at Anyinam (*loc. cit.* Appendix V), Dade has advocated the extensive planting of shade trees, using *Samanea Saman* in the first instance, throughout the cacao areas of the Gold Coast.

Nigeria.

Cacao is confined almost entirely to the South-Western Provinces, although a little is grown in scattered areas in the Eastern Provinces. Experience gained over a number of years, suggests that there are three primary factors which can cause die-back in this country. They can be distinguished by the symptoms they produce, as follows :—

(i) *Drought.* The effects of drought become most marked towards the end of each dry season. In trees of all ages the twigs and branches die back slowly. The leaves hang flaccidly and then *turn yellow and fall* off, leaving the twigs bare. Nearby secondary vegetation shows similar symptoms of lack of soil moisture at the same time.

(ii) *Blast.* Blast is the name we have given to the damage caused by Sahlbergella spp. The life history and habits of both species of Sahlbergella have been fully described by Cotterell (6). Twigs and even whole branches die quite rapidly, and the *dead brown leaves remain hanging on them* for a considerable length of time. Attacked trees have the appearance of having been scorched by fire. Small discoloured areas can be seen on the petioles and stems of young shoots which are in the process of wilting. Older branches show deep lesions of varying size which sometimes develop into definite cankers. The secondary vegetation remains green and healthy under cacao showing Blast.

(iii) *Unsuitable soil.* This is exemplified by general debility in the growth of the cacao plant. The main cacao producing area of Nigeria occurs on a soil derived from a granitic formation. The Department has failed to establish cacao on the Benin sands and on the soil types of the Eastern Provinces; failure has also followed the attempts of native farmers in these areas, and it is very rarely that one sees a cacao farm fully established. This is all the more surprising in Benin Province, the southern portion of which supports magnificent virgin forest and enjoys a well distributed rainfall of 70"-90". Rather different soil conditions exist in the south of Ondo Province. This soil appears to be mainly transported sand derived from the granitic formation. Cacao has been established here, but severe die-back has occurred for which Blast cannot be held entirely responsible. The greater portion of this area is under virgin forest, and lies within the 65"-75" rainfall belt. We therefore recognize that soil type influences profoundly the occurrence of die-back.

Experience Obtained in Experimental Farms.

As will be seen from the rainfall sketch map the South-Western Provinces include areas of optimum and minimum rainfall, when judged by the accepted standards of cacao moisture requirements. Our experiences in establishing the cacao experimental farms at Owena, in Ondo Province, and at Ina, near Ibadan, may be taken as accurately indicating the factors which affect cacao in these areas. Owena was planted in 1935 and two years later Blast broke out severely, incidentally in some of the best shaded plots. Mr. F. D. Golding, Senior Entomologist, identified the majority of specimens collected in the farm as

Sahlbergella theobroma. So far, hand picking has proved an efficient control measure, but this may not hold true when the trees become larger.

Ina was planted in 1934. Until adequate side shade was obtained, establishment was extremely difficult owing to the lack of soil moisture during the dry season. Figures as low as 2 per cent. of moisture in the top foot of soil were obtained at Ibadan by Mr. H. C. Doyne, Senior Chemist, during the dry season of 1938-39 when conditions were less severe than usual. A proportion of one year old cacao seedlings will die simply because their roots have failed to reach the deeper levels of more abundant moisture. Yet cacao seedlings planted in petrol tins can be maintained in a condition of vigorous growth throughout the dry season, without any shade, provided the soil is kept adequately moist.

Isolated patches of Blast do exist in mature cacao farms in the Ibadan area, and specimens collected in them have been identified by Mr. Golding as *Sahlbergella singularis*.

Summary of Theories.

In condensed form the theories regarding the causes of die-back in these countries are as follows :—

(i) Lack of soil moisture during the dry season. Ibadan, Nigeria. The Gold Coast.
(ii) Excess of soil moisture at certain periods. Sangre Grande, Trinidad.
(iii) Lack of manure and forking. Grenada.
(iv) Unsuitability of the soil. Agbabu, Nigeria. Trinidad.
(v) Sahlbergella Blast. Ondo, Nigeria.

As distinct from die-back, there is a form of dying out which is recognized in nearly all cacao growing countries. In an established farm a single tree is killed through some agency, and the cacao canopy is broken. In succeeding seasons adjacent trees die, and an expanding open is created within the farm. The general term "exposure" is used to explain this form of dying out. Possible causes are :—

(i) "Exposure"; soil deterioration; lessening of soil moisture; lessening of atmospheric humidity; direct solar effects on the trees.
(ii) Further action of the agent causing original break in the canopy.
(iii) Ingress of insects.

Observations in the Gold Coast.

The detailed observations made by us in the cacao areas of the Gold Coast visited are contained in Appendix I. There appear to be two distinct sets of conditions in which die-back occurs :—

(i) The "Dry" areas; Bisa. Asuansi-Swedru-Nsawam. Generally less than 55 inches of rainfall.
(ii) The "Wet" areas; Koforidua-Kumasi-Bekwai. Generally over 55 inches and mostly over 60 inches.

(i) *The "Dry" Areas.* More particularly in the Bisa district, the symptoms of die-back were identical with those which in Nigeria are associated with drought. This applied both to the cacao itself and also to the secondary vegetation. Thomas (7) expressed the opinion some years ago that around Bisa the deterioration of the cacao was due to drought, and that it was usually more marked in places where the soil had an acid reaction. This deterioration has proceeded to such an extent that much of the land is now reverting to secondary bush. With the exception of a heavily shaded farm in a valley, we found practically no sign of recent Sahlbergella damage. On the other hand, trees suffering severely from die-back were producing that flush of strong basal chupons which is a characteristic of drought die-back.

A similar absence of insect damage was apparent in cacao farms along the route Asuansi-Swedru-Nsawam. Here a certain number of forest trees had been left in the farms, as opposed to complete deforestation which had been practised round Bisa.

(ii) *The "Wet" Areas.* We were informed that the dry season of 1938-39 had been much wetter than usual. That soil moisture was abundant was amply borne out by the types and condition of the secondary vegetation. The luxuriant growth of coco-yams (tannias), ferns and plantains in the farms, the presence of green moss and epiphytes on the cacao trees, the healthy appearance of "squirrel sown" cacao seedlings and the dampness of the soil itself were most striking features. On the other hand, the extremely common occurrence of cacao Blast, both in mature and young trees and the presence of numerous Sahlbergella spp. feeding on the shoots were equally noticeable throughout these areas.

We are uncertain as to how far the damage caused by Sahlbergella spp. was augmented by other insects, but we are convinced that, in contradistinction to Dade's theory of *drought* die-back, insect attack was responsible for the actual *killing* back of the cacao in these "wet" areas. As stated above, 1938-39 was apparently an abnormally wet dry season. Had drought been the cause of die-back we would have anticipated a reduction of the die-back symptoms. We were informed, however, that die-back was just as severe as usual at that time of year.

Discussion.

In the Gold Coast it appears that, whereas in the early years of the development of the cacao industry a farm was expected to commence bearing after four years, it is now estimated that there is a lapse of as much as ten years

between planting and first reaping. During this period the native farmer apparently considers it necessary to allow the young cacao to remain in "bush"; whether this measure prevents the production of shoots sufficiently attractive to Sahlbergella or whether it provides a form of direct mechanical protection against Sahlbergella is debatable.

Even in the early days the serious nature of Blast was recognized by the native farmer. Cotterell (*loc. cit.*) states . . . "The TWI name 'Sankonuabe' was given to the pests in the early days of cocoa and means 'go back to your oil palm,' the production of palm oil being the staple industry of the country prior to the introduction of cacao. It indicates the importance given to the pests by the native farmer at the time when he was commencing to build up the enormous export crop we have to-day".

The double nature of Sahlbergella attack is amply illustrated in the cacao farms of the "wet" areas. Where the overhead canopy is broken through insect damage, a luxuriant growth of ferns springs up in the soil thus exposed. Figure 4 in Wright's report (8) shows this type of growth. As soon as cacao seedlings planted in these spaces attain sufficient size they are in their turn attacked. Consequently the mature trees are killed back each year, and there is extreme difficulty in replacing them with younger plants. We were unable to observe any correlation between the amount of overhead shade and the degree of insect damage. At Tafo itself the figures given by Wright (*loc. cit.*) show there are approximately 25 forest trees to the acre, but this type of shade has not prevented the occurrence of severe cacao Blast. The typical amount of shade which is found in native farms in these areas is indicated in the right hand back-ground of Figure 2 of Wright's report. At Bunsu young cacao growing under mature Hevea rubber was very badly attacked, and Sahlbergella damage was noticeable in the departmental cacao plots at Kumasi and Asuansi where good shade is afforded by Rain Trees (*Samanea Saman*).

In Nigeria, Owena (only 15 acres in extent) is, we consider, another example of Blast attacking cacao grown under good shade and protected on all sides by virgin forest.

In Nigeria we hold that Blast is a primary factor in certain of the wetter areas. It is the personal opinion of some officers in the Gold Coast that drought is the primary factor in all areas and that, in the "wet" areas, it induces in the cacao a habit of growth suitable for Sahlbergella attack.

One of us (O.J.V.), who has recently worked on cacao in Trinidad, considers that more damage is done to the cacao industry in the wetter portions of the Gold Coast and of Nigeria by Sahlbergella Blast than is caused in Trinidad by Witch Broom Disease.

We heard the opinion expressed in the Gold Coast that deforestation has brought about fundamental changes in the atmospheric conditions. Although we accept this as a legitimate point of view, we were shown no figures to prove that such a change had taken place since cacao was introduced into the Colony. Such figures as are available fail to indicate any such change in Nigeria. We have deliberately stressed the primary factors causing die-back. At the same time we realise that their effect is accentuated or mitigated by the interaction of all factors which make up the environmental complex. As an example, we suggest that Blast, working over many years, was the primary factor at Akodum and that its cumulative effect became fully apparent in a season of abnormally light rainfall. Similarly the soil type will allow the cacao to withstand the effect of another primary factor either for a limited or an indefinite period. Thus in the Ibadan areas the effects of drought die-back are more severe on a sandy as opposed to a clayey type of soil. Moreover, we have learnt to anticipate greater difficulty in establishing young cacao on such sandy types, other things being equal.

General Conclusion.

Experience has shown us that cacao die-back is not due to one cause alone. We recognize three primary causes of die-back in Nigeria.

(i) Drought; a lack of soil moisture during the dry season, such as occurs in the Ibadan area.

(ii) Sahlbergella Blast, associated with the wetter conditions prevailing in Ondo Province.

(iii) Unsuitability of the soil, as is found at Benin.

Similarly we consider that in the Gold Coast there are two primary factors, *viz.*: drought and Sahlbergella, causing die-back in the drier and wetter cacao areas respectively.

Since die-back is the expression of one of several primary adverse factors, it does not follow that a single control measure will prove effective in every case.

Appendix I.—Detailed Observations.

Aburi.

A typical situation; high elevation, heavy dews and high air humidity, comparatively low rainfall. Old cacao growing very well under full Rain Tree shade. Helopeltis damage on pods, but no severe Sahlbergella attack; no sign of drought die-back.

Tafo Station.

Large number of forest trees left as shade compared with Nigeria; not clear whether left to act as shade for cacao or because too much labour to clear. Ample soil moisture as typified by general vegetation. Apparently exceptionally wet dry season. No sign of drought. Very extensive Sahlbergella damage in trees of all ages; Helopeltis possibly also active. Healthy ground flora of coco-yams and/or ferns and bush growth coming in where overhead canopy had been damaged by insect attack. One bad patch dying out on sandy soil near stream; high water table. Unpublished figures of Wright on the growth of cacao show no correlation between shaded and unshaded trees.

FIG. 1.—Five year old cacao unattacked by Sahlbergella. Note absence of overhead shade.

FIG. 2.—Trunk of ten year old cacao tree. The canopy has been destroyed and the suckers arising as a result of this have recently been attacked by Sahlbergella. Except for the lowest four leaves, all are dead.

FIG. 3

FIG. 4

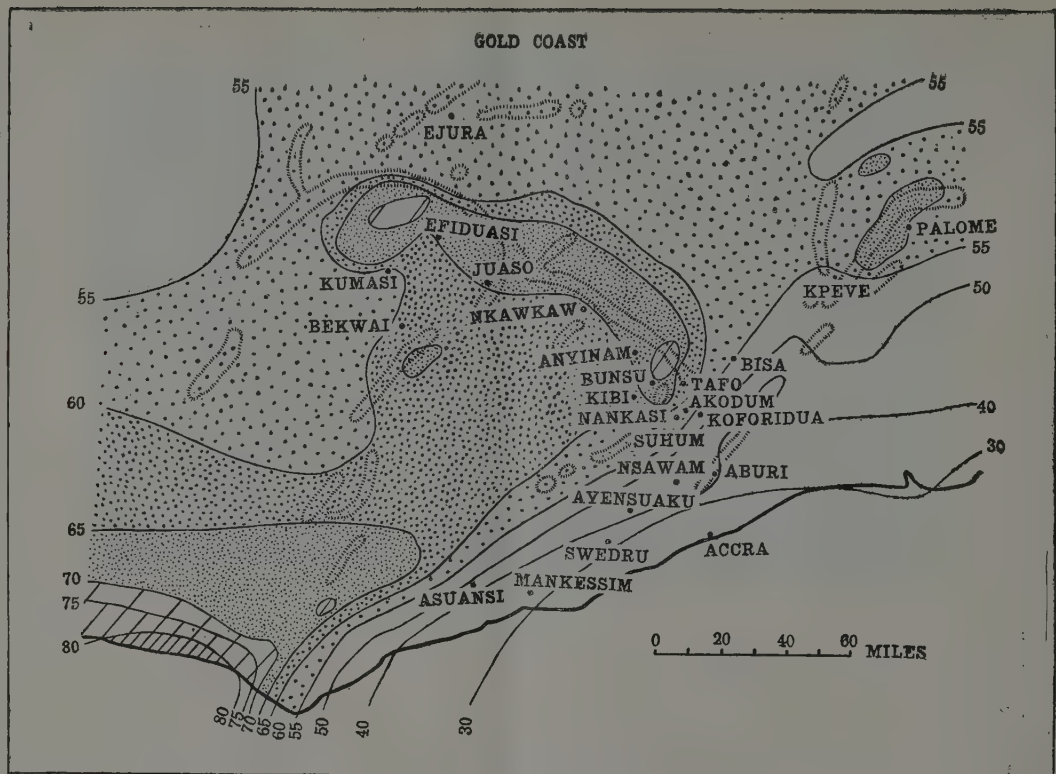
FIGS. 3 AND 4.—Nine and ten year old cacao showing early stages of Sahlbergella damage in the canopy.

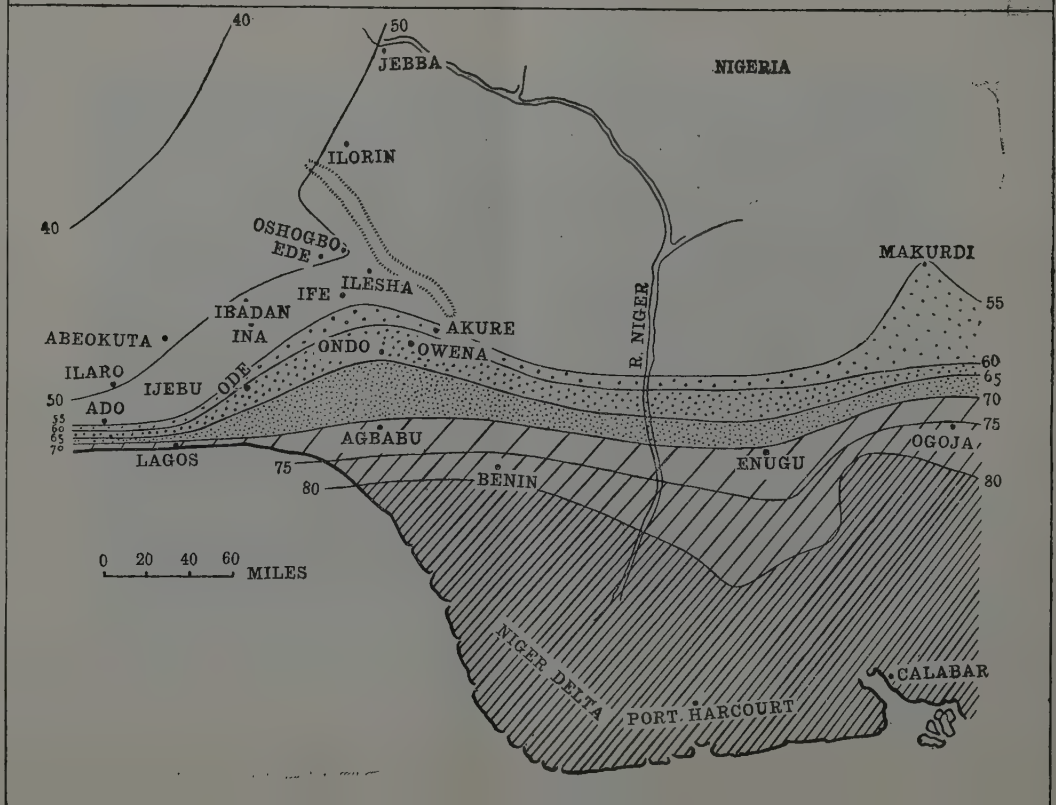
FIG. 5

FIG. 6

FIGS. 5 AND 6.—Eleven and twelve year old cacao showing last stages of Sahlbergella damage. Ingress of ground flora.

SKETCH MAPS SHOWING THE MEAN ANNUAL DISTRIBUTION OF RAINFALL IN THE CACAO PRODUCING AREAS OF THE GOLD COAST AND NIGERIA.





1. The Gold Coast sketch map is based on the Departmental rainfall map. The Nigerian sketch map is based on official data, collected and analysed by Mr. F. D. Golding, Senior Entomologist.
2. To facilitate comparison, the same isohyets have been used in each map, although the coastal regions of Nigeria are considerably wetter than is indicated.

Akodum.

Extensive areas of large mature cacao dying or completely dead. Soil not as sandy as the stream and river verge type, but a very much lighter colour. Notable absence of secondary bush where cacao had died; absence of overhead shade; ground flora of grassy nature. No signs of drought; live moss on dying trees. Patches planted up with cassava and young cacao; young cacao appeared to be doing well. No obvious reason why cacao in this area should have died.

Nankasi.

Areas of old cacao, on smaller scale than Akodum, dead or dying. Farms with trees about 10 to 15 years old being killed back by Sahlbergella; ground flora of ferns and cassava. No signs of drought. Cacao supplies in these farms showed good growth; extremely badly hit by Sahlbergella. Possibly Akodum represents the final stage; poor appearance and dying back at Nankasi can definitely be attributed to Sahlbergella.

Suhum : Rest House.

On top of hill mature cacao healthy; no shade. Site overlooks an area of excellent cacao intermingled with patches showing severe Blast.

Bunsu.

A very damp area. Exposed cacao, recently cleared from bush, situated near stream and having ample soil moisture, very badly hit by Sahlbergella, and possibly Helopeltis. Adjacent cacao higher up from stream, shaded, good condition, not heavily attacked, not flushing. Cacao showing Blast was typical of sandy stream verge type, depressed by Sahlbergella.

Individual mature cacao trees growing exposed between road and river, healthy appearance, no insect damage.

Younger cacao under very heavy shade and in bush, growing very strongly; no die-back; no Blast; isolated. Field of older cacao under similar conditions looked good; yield unknown.

Young cacao growing under Hevea rubber showed severe Sahlbergella damage.

Very old cacao plot near river. One end beginning to die out, perhaps because of "exposure".

Cacao seedlings in adjacent plot, interplanted through mature cacao under Rain Trees; no side shade; in excellent health. Too young for Blast.

Bisa.

A dry looking area; soil entirely different in appearance. Cacao first few miles out of Koforidua looked very good; no shade; hilly country. Nearer Bisa cacao had died out; reversion to annual crop farming. Typical drought symptoms in cacao and secondary vegetation. One farm being replanted; banana side shade; cacao one season old looking healthy, too small for Sahlbergella attack. Another farm, by stream and heavily shaded; young and old cacao very badly hit by Sahlbergella.

Anyinam.

Two of Dade's plots visited. In one Rain Trees had been ring-barked by farmer to reduce shade; old cacao very poor underneath; moist type ground flora. In other, a farmer had cut out shade several years ago. No apparent difference between cacao in these two and in surrounding farms. Sahlbergella damage universal.

Anyinam-Nkawkaw.

Extensive forest; well watered area; small patches of cacao growing; severe Blast.

Nkawkaw-Juaso.

Very little cacao seen from train; bush or high bush; generally a sandy type of soil.

Juaso-Kumasi.

Patches of cacao and high bush. No signs of drought; severe Blast prevalent.

Kumasi : Departmental Plots.

Cacao very patchy; growing under mature Rain Tree shade; young and old trees showing Blast; no signs of drought.

Efiduasi.

Unit cacao farm. Cacao younger and very fair. Considerable overhead shade. Supplies planted last season; no side shade; looking excellent. Ferns and coco-yams again; no drought conditions.

Kumasi-Ejura.

Patches of cacao intermingled with bush; severe Blast. One isolated small cacao farm within forest reserve at top of scarp showed severe Blast.

Kumasi-Asuansi.

Best cacao seen in hilly range south of Bekwai; from there nearly to Asuansi mainly forest or tall bush; apparently sandy type of soil, wet conditions.

Asuansi : Departmental Plots.

Cacao uneven; young or rejuvenated trees and some of the old trees were badly attacked by Sahlbergella. Heavy shade near stream.

Asuansi District.

Not much cacao; very fair condition; very little insect damage.

Asuansi-Swedru.

No cacao seen till near Swedru. Cacao looking very fair; no obvious Blast; a certain amount of overhead shade.

Ayensuaku.

Unit cacao farm. Surrounded by large continuous areas of cacao. Cacao showing die-back; drought conditions; very little sign of Sahlbergella damage.

Ayensuaku-Nsawam.

Cacao very fair; drought conditions; very little Blast.

Kpeve : Departmental Plots.

Mature cacao in excellent condition. Borer damage prevalent in trunks and stems. Blast not obvious.

Kpeve District.

Patches of cacao looking very well. Blast not apparent.

Appendix II.—Illustrations.

The photographs illustrating this article show healthy and Sahlbergella attacked cacao. We were unsuccessful in obtaining photographs in the Gold Coast, but the six presented here, taken in May, 1939 near Owena, Nigeria, are typical of Sahlbergella damage in the wetter regions of the Gold Coast.

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SOIL CONSERVATION IN THE TROPICS.

The following article, reprinted from the "Agricultural Periodical" (Monthly) of the Netherlands Society for Scientific Agriculture, 51st Vol. 1939, is a copy of a short paper read by Sir Frank Stockdale, K.C.M.G., C.B.E., *Agricultural Adviser to the Secretary of State for the Colonies, at the request of the organizers of the Conference on Tropical Agriculture which was held at Wageningen, Holland.*

As far as the British Colonial Empire is concerned, it is just sixty-five years ago since attention was directed to the question of soil erosion. It was in 1873 that Sir Joseph Hooker, then Director of the Royal Botanic Gardens, Kew, drew the attention of the Secretary of State for the Colonies to the serious losses of soil which were taking place in Ceylon as the result of the opening for cultivation of the forest-clad highlands of that colony. As the result of this action, legislation was some years later enacted prohibiting the alienation of Crown lands, except in small areas for very special circumstances at all elevations in excess of 5,000 feet. Similar enactments were passed from the year 1912 onwards in the mountainous islands of the West Indies for heights varying from 1,000 to 1,500 feet according to the particular island concerned.

This system of protecting the forest cover at the higher altitudes of island colonies constituted the first steps which were taken in the British Colonial Empire to deal with erosion. It is satisfactory in the hilly wet tropics only if measures are also taken to prohibit the opening of steep slopes and to protect the catchments and springs of the principal streams at lower altitudes. All lands opened for cultivation purposes must, however, be specially protected by anti-erosion measures if severe losses at top soil are to be prevented.

I personally began to take an active interest in soil conservation work in the tropics from 1920 when as Director of Agriculture in Ceylon it was apparent that much further protective work remained to be done on the tea and rubber estates in the hilly parts of that island if the enormous losses of soil from erosion were to be checked. The experiences of the Netherlands East Indies were freely drawn upon for control measures adopted and during my service in Ceylon I saw considerable advances made. Clean weeding practices were slowly, but gradually, abandoned, contour drains and silt pitting increased, low contour stone walls established, the general growing of cover crops begun and the contour platform system in the opening of new lands started. Many were sceptical at first, but progress was made by degrees as the result of experiment, education and propaganda. The results achieved up to 1930 were reviewed by a special Government Committee constituted to examine the position. In the Report issued by this Committee in the following year there was expressed general commendation of the improvements which had been effected during the previous ten years but it was stressed that the position was still regarded as serious. Estate agriculture was considered to be mainly responsible for erosion in Ceylon and it was held that it was essential that the use of ground cover should be universally accepted, as it was only by the adoption of such a policy that erosion could satisfactorily be checked. In recent years, attention has been given also in the village lands and some useful demonstration areas started.

Since 1931 much attention has been focussed throughout the world on the problem of erosion and also on the measures which can be effectively employed to assist soil conservation. The position in the United States which was made clear to the world in the Report of the National Resources Board of 1934, and the action taken as the result of that report, has attracted universal attention. Those who were battling in the Colonies fifteen years ago to secure some recognition of the evils of and losses occasioned by erosion, have seen the Governments of colonial dependencies inundated with demands for something to be done and with complaints that anti-erosion work is not proceeding sufficiently rapidly. There is no British tropical possession in which a review of the position has not been made and, where necessary, some measures undertaken to improve matters. Public opinion has been aroused, but not infrequently the staffs available for the work are insufficient and finance inadequate. It has been recognised, however, that considerable expenditure will have to be incurred and that the most satisfactory results will only be achieved when there is planned co-operation between administrative and technical staffs and the people themselves.

When questions of soil conservation are under consideration it is necessary to contemplate the issues involved in their broadest aspects. They must include not only the consideration of forest protection and anti-erosion measures but also those associated with the maintenance of soil structure and fertility. The reactions of vegetation on soil and possibly climate have their bearing on the general problem, as the whole concept of soil conservation covers the maintenance of its productivity. It is bound up with soil cover, the nature of the soil, the conservation of water supplies, the forestry position, the agricultural occupations of the people concerned and their social and tribal customs.

Accelerated Erosion.

Accelerated erosion occurs in the form of sheet erosion, water erosion or wind erosion. It is brought about by an interference with the natural vegetal cover, by the omission of suitable anti-erosion measures and the lack of satisfactory methods of agricultural husbandry and of grassland and woodland management. The unthinking stripping of the soil's protective covering of vegetation is primarily responsible, but densities of population and developmental enterprises have required that large areas of hilly lands should be brought under agrarian production.

As far as the tropics are concerned, it is necessary to keep clearly in the forefront of any consideration of the subject the differences between the wet and dry tropics. It is necessary, however, to recognise that the distribution of the rainfall is of greater importance, as far as erosion is concerned, than the actual total falls. Downpours of high intensity over comparatively short periods of duration invariably cause the maximum of "run-off" and erosion is always more serious in areas where long periods of dry weather are experienced than in those where a more even rainfall distribution prevails. In some areas of the wet tropics erosion is not nearly so severe as might be expected because of its more regular spread throughout the whole year. Whereas in the dry tropics the soil during periods of drought is often reduced to dust which may be carried away by the wind or eroded by the heavy tempestuous storms which herald the break of the dry weather season, this dusty soil is but poorly absorbent and in consequence it takes little to remove it from its normal situation.

Again, the configuration of the country must be another factor to receive consideration. The steeper the slope, other things being equal, the less the time for water absorption and in consequence the greater the "run-off". The aspect of the slope is also important, for hilly slopes which face the direction from which prevailing rain storms come, suffer more than those which are favoured by a measure of protection. The size and shape of the watershed also must not be overlooked when the opening of lands from forest or grassland cover is under consideration and a decision being made of the anti-erosion measures to be adopted.

Consideration must also be given to the kinds of vegetation and the extent of the land cover. Forest cover is recognised as affording an ideal protection against erosion. Tree roots bind and hold the soil, leaves and branches break the velocity of the rains which would otherwise compact and erode the soil and the ground cover of forest litter provides that the water is rapidly absorbed, the velocity of surface water from hilly slopes reduced and "run-off" prevented. It is the organic litter in the forest which encourages the absorption of water and checks "run-off," but at the same time the more satisfactory soil structure under the forest litter must not be over-looked. Soil under forest cover invariably has a better structure than is the case when a similar soil is subject to cultivation for a number of years.

It should be the aim of all agriculturists in the wet tropics to maintain or to reproduce as far as is practicable the conditions which prevail when the land is under forest cover. Tree crops which produce a good canopy of foliage are more suited for cultivation in these areas than are annual crops which require frequent cultivation. Where the nature of the crop does not permit of forest-like conditions being re-created, the use of contour drains, silt pits, terraces and ground covers is necessary if "run-off" is to be effectively checked.

In effecting control in the use of land so that erosion may be checked it is important to recognise that it is necessary to protect by means of forest reserves or in grassland cover the major catchments and water sheds, provide for the protection of stream banks and steep hill slopes and prevent the destruction of the natural vegetation on the poorer lands.

In the dry tropics, the position differs from that which obtains in the wetter areas. Here the principal activities which are causing injury to land are shifting cultivation, bush firing, increased agricultural activities and in some places overstocking with cattle and goats. The consequences of the exposure of vegetation to these abuses are a general deterioration of environment, soil degradation, a failure of water supplies and erosion. In many areas in the dry tropics, forest cover is sparse, and in others savannah or grassland prevails. It is only in recent years that grassland problems have been intensively studied in temperate countries and the work has barely begun in the tropics. Data are available which show that "run-off" from grass covered areas is practically nil and that from an erosion point of view they provide efficient cover. In fact it is now recognised that fibrous rooted crop plants are more effective in providing for water absorption than are tap rooted plants and that a good cover of grass will minimize erosion and increase infiltration of water. If, however, these grasslands are, as is so often the case, overstocked with stock concentrations the soil cover is rapidly eaten down or trampled out. Erosion then becomes serious. Similarly, agricultural cultivations in grassland areas can readily become the cause of extensive gully erosion.

The damage which can occur in grass covered country from overstocking or thoughtless agricultural activity can be seen in many parts of East Africa today.

In dry areas also much damage is occasioned by the annual burnings which occur. These cause a definite retrogression in the growth of vegetation and the absorptive capacity of the surface soil is greatly reduced.

Wind erosion is severe in only the driest areas and occurs only when the vegetation has degraded or has been removed for agricultural occupation. The loss of soil structure is one of the main causes responsible for making a soil liable to wind erosion. In areas liable to wind erosion measurable improvements can be effected by strip cultivations and by rough methods of cultivation which attempt the burial of but a portion of the crop residues. It is only when the pressure of population becomes considerable that lands in dry areas liable to wind erosion should be taken up for arable cultivation.

Protection cannot perforce be carried to the extreme as the populations must produce their food for subsistence and some money crops wherewith to secure the cash for the purchase

of clothing and other requirements. It is therefore now necessary to consider the measures of control against erosion which have been shown to be effective.

Measures of Control.

These vary in accordance with the particular circumstances of the case. They have been devised by man to counteract the troubles which follow upon his thoughtless action in regard to land. It is unnecessary to go into them in any great detail in a paper prepared for an audience such as that gathered at this Conference. Neither is it necessary to quote figures from the results of experiments designed to ascertain the amount of soil lost under ranging forms of treatment, nor to list the comparative efficiency of the different methods of control. Year by year additional data are being added and from the results secured our knowledge is steadily increasing. The whole essence of the problem is to remember that the measures which require to be adopted in any particular area depend upon the special circumstances of the case. Generalizations are dangerous and each area and each problem must be examined in detail before any particular line of action is advised.

In Kenya, for instance, where attention has in recent years been centred in erosion problems, it is recognised that the chief causes of erosion have been the following:

1. The deforestation of the hill tops and slopes and sides of river valleys.
2. The depletion of grassland cover by reason of a general increase in cultivation.
3. The cultivation of steep slopes.
4. Gross overstocking in certain areas leading to a destruction of the vegetal cover, and
5. The concentration of stock at and around water supplies, particularly during the dry season.

In any particular area one of these causes may be of more importance than the others, whilst in another area there may be operative a combination of two or more of them. Each cause of erosion demands specific remedies and it is frequently necessary to combine a number together. Progress is often slow by reason of economic and sociological considerations which have to be given most careful thought and consideration.

It has been demonstrated in the United States of America and elsewhere that erosion cannot be effectively checked in areas where the main cause is over-stocking unless and until the number of stock is reduced to the normal carrying capacity of the land and it is clear that in many parts of East Africa similar action will have to be contemplated if the people are to be saved from themselves. In the tropics it is not always easy administratively to secure the adoption of this necessary measure of control because of tribal customs, especially in areas liable to serious outbreaks of epizootic diseases and severe droughts, but it is recognised that it is useless to introduce contour banks or spreading works without controlling the grazing and that one of the most important measures to demand attention in dry land grazing country is the provision of adequate and satisfactorily spaced water reservoirs or dams for the stock in order that they may be spread over a wider area and excessive concentrations in particular areas reduced. Gradually, as economic considerations become more recognised by the people, improvements will be effected and more satisfactory systems of range management introduced. Economic advantages inevitably lead to the adoption of measures which at first are difficult to secure by reason of the conservatism of the people concerned.

The conditions in the wet tropics are different from those in the drier areas such as those mentioned above, as being applicable to Kenya and the endeavour must there be made to reproduce as far as is practicable the conditions which prevail in the natural conditions of the forest. Successful agricultural undertakings in the wet tropics, if one excepts the rice cultivations under irrigation, have as I have already mentioned been found to be the tree crops of which rubber, tea, cacao, nutmegs and oil palms may be mentioned. These form a satisfactory leafy canopy and where they do not the introduction of shade trees has been beneficial and the establishment of ground covers adopted. The organic litter which is thereby created plays an all-important part in the control of erosion and this supported by such provisions as platform terraces, box terraces, contour hedges, contour drains and silt pits normally ensure a reasonably stable condition.

It is unnecessary to give constructional details of different forms of terraces and pitted contour drains nor is it necessary to refer to the systems of broad base or narrow contour banks which have been employed successfully in undulating country of medium or low rainfall.

The use of contour hedges or contour strips of mulch have been shown to be effective in several areas and I have seen in parts of Tanganyika and Kenya marked improvements follow upon the adoption of the former and in Uganda the advantages of the latter. The use of contour strips of mulches of elephant grass (*Pennisetum purpureum*) in Uganda has also shown an inexpensive method of inducing the formation of terraces on gentle slopes of friable soils.

Strip cropping is also being employed with success. It can be used on moderate and ungullied slopes whilst contour buffer strips of close growing grasses or cover crops are also effective in certain places.

Recent investigations have also shown that roads paths and fire breaks must receive attention in connexion with any anti-erosion measures and that it is of the greatest importance that most careful consideration be given to the natural drainage channels. The use of vegetation as covers in these water outlets is preferable to the construction of engineering works and the whole tendency of modern thought to-day in regard to anti-erosion measures is to encourage Nature to do her rightful work and to enlist her aid in every manner possible. The aim should be to

get away from engineering structures as far as possible and to make the fullest possible use of vegetation. This is the most economical system and produces the most lasting results.

Soil Structure.

I will now briefly turn to the question of soil structure. Steadily it is becoming recognised that many of our agricultural difficulties have resulted from a loss of soil structure. Sheet erosion, that most insidious form of soil loss, is often unrecognised at the outset. It may not attract attention until finger or other forms of gullies begin to occur. In Uganda, for example, there has been a progressive increase of sheet erosion since the extension of cotton cultivation became general and it is now recognised that, except in a few areas of that country, the soil losses which are being experienced are due mainly to a loss in soil structure.

Soils under forest cover have as a rule a satisfactory soil structure. The decaying roots and the decomposition of the organic leaf fall are responsible for this, but general conceptions of soils have changed markedly in recent years. From the geological conception we have been introduced to the biological conception. This in turn has been shown to be but part of the whole story and now our thoughts are being directed to the importance of soil crumb, for without a satisfactory soil crumb water absorption is unsatisfactory, biological activities are affected and fertility reduced. In a soil of good structure the mineral particles are cemented together by the colloids into water-stable crumbs, and where the soil crumb has been lost the soil particles become more dust which may be blown away by the wind or carried down the slopes by every shower. Optimum crumb size varies with different soils and under differing climatic conditions. It may be defined as that which best secures adequate supplies of air and water for plant existence. In wet climates the limiting factor is the air supply whilst in arid climates water is the controlling influence. It follows therefore that in the wet tropics an open soil structure is preferable whilst in the drier tracts a more compact soil structure is desirable. Martin in Uganda is finding that soil structure can be markedly improved in the cotton-growing belt by the use of rotational growths of elephant grass (*Pennisetum purpureum*) between crops of cotton and food crops. He has in fact found the improvement of soil structure is better under grass, with its masses of fibrous roots, than when green manures are employed. Similar results, although perhaps not quite so spectacular, are being obtained in the drier areas where permanent star grasses (*Cynodon* spp.) are being employed in the place of elephant grass.

This work appears to be of importance and it may lead to a definite form of alternate husbandry, with, say, three-year periods of arable alternated with similar periods when the land is under grass. The system is not very different from that which is now finding favour in England where arable cultivations are being alternated with leys of grasses and clovers for periods of three years upwards.

If the results in Uganda come up to expectations, the change of system is expected to find favour, because it approximates in an organized form to the methods of the shifting cultivations in the grass covered areas.

Soil Fertility.

Within certain limitations, a soil owes its character rather to the effects of climate and vegetal cover than to the nature of the parent rocks. Removal of cover and exposure to the sun tends to speed up the chemical processes, while rainfall is responsible especially in the wet tropics for excessive leaching of plant nutrients if the soils are exposed.

In the wet tropics, the luxuriance of evergreen vegetation conveys an impression of considerable soil fertility. This has led to the clearing of areas formerly covered with heavy forest for cultivations of both permanent and annual crops. In regard to the latter, many have been the disappointments. Deprived of the products of decay of the forest vegetation the soil has proved to be unproductive and the cleared areas have been abandoned to a useless and often sparse weed growth. Mohr, in his article on "Climate and Soil in the Netherland Indies" has pointed out that heavy rainfall causes leaching and impoverishment of the soil. Under virgin forest conditions, plant nutrients form a kind of closed cycle, whereby the plant food taken from the soil is returned in the form of plant residues ; but when that cycle is broken and crops are taken from the land a loss of fertility begins. This loss of fertility may be excessively rapid under the conditions prevailing in the wet tropics and I have seen excellent forest lands opened for pineapple cultivation reduced to infertile white quartz sands within a period of three years.

Hardy has shown in respect of cacao that the chief nutritive feature of organic matter in cacao cultivation is its content of mineral nutrients and that importance should not be placed on nitrogen to the extent to which it was at one time customary. The results which are being obtained from the use of phosphatic manures in rubber cultivations in the East also tend to support this view.

In the drier tropics, attempts have been made to introduce mixed farming, whereby animal husbandry is introduced into the agricultural system of the small holder for the purpose of producing supplies of organic manures. In Northern Nigeria progress has been made, but here again except for the value of the organic matter in the building up of soil structure it has been determined that the increases of crop yields have resulted from the phosphatic nutrients of the manure added. Attempts are being made to encourage the spread of mixed farming in many parts of the British Colonial Empire and large numbers of experiments are being carried on. It has yet to be ascertained whether the sytem can be introduced effectively into the wet tropics where, as has been previously stated, it is now recognised that permanent tree crops are more suited to the prevailing conditions than annual arable cultivations.

Trials are also being made with the use of composts. Their value has been demonstrated in nursery work and in garden cultivations but it is doubtful if the preparation of composts is economically sound for large scale cultures, especially in areas where the rainfall is adequate to ensure a satisfactory break down naturally of organic waste materials within a reasonable measure of time. In the dry areas, the position may possibly be somewhat different if adequate water supplies are available for the making of good composts. From a soil erosion point of view, however, it must not be overlooked that vegetable wastes and stubbles can be usefully employed as part of anti-erosion measures. I would be very loath to see, as I have done recently in Ceylon, the general adoption of a system of clearing undulating land free of waste vegetable matter for conversion into compost to be transported back to the area from whence it came. This is a most wasteful method and one which is liable to encourage an increase of erosion.

With the use of green manures considerable successes have been achieved in the Netherland Indies but our experiences in the British colonial dependencies have been variable. In Ceylon and Malaya their use has been advantageous and in Nigeria it has been demonstrated that soil fertility can be maintained at a reasonable level by their use. In East Africa, however, their use has not brought about the results which were expected and except where pigeon pea (*Cajanus cajan*) is being employed for the breaking up of lateritic hard pans there is a tendency now to await the results of the experimental work designed to test whether the improvements of soil structure which result from land being sown or planted with grass as part of the rotation are not of greater value than those which follow upon the employment of green manuring. A strong cultivation of grass or a healthy grass sod produces new roots each growing season to replace the older ones which in their turn add to the soils organic matter. When land is under a grass sod the organic matter in the soil is increased and workers with sugar-cane in Hawaii hold that the amount of roots annually produced by a crop of sugar-cane adequately maintain a soil's organic matter content. I am aware of lands in British Guiana which have been under sugar-cane continuously for nearly 100 years, with only those breaks at intervals of 3–4 years when replanting had to be done. Grassland soils are generally richer in organic matter under comparable conditions than are forest soils and we are, I fear, rather inclined to overlook that the grass lands which are associated with the dry tropics often mean poor soils because of low rainfall and stunted growth of the vegetation rather than an intrinsic harmfulness which has so often been ascribed to the grasses themselves.

Conclusion.

In conclusion, I would like to say that I have endeavoured to treat this subject of soil conservation, which is attracting world wide attention, in as comprehensive a manner as time permits. Science in recent years has tended to become departmentalized into a series of narrow specialist channels. Co-ordination is often difficult to secure and a clear picture of the whole impossible to obtain. It is the same with matters concerning soil conservation. There are the enthusiasts for certain particular remedial measures and also those who tend to ride their pet hobby horses. But we must approach the subject from a much wider view-point if sound progress is to be attained.

Much time, energy and money has been expended in many countries on the treatment of gullies which are but the indications of troubles further away at the head of the drainage systems. Similarly much time and energy has been expended on the development of terraces, contour bundings and other works in areas where the methods of agriculture are faulty.

One knows full well that circumstances in many tropical countries demand immediate and energetic action if increasing losses from erosion are to be checked and ultimate economic ruination prevented. Sound planning of land usage is essential but without sound methods of agricultural husbandry and range and woodland management attempts to check erosion will be of but temporary value. Soil conservation in its truest sense will not be achieved unless it is tackled in the widest possible way. The building up of deteriorated soils is a relatively slow process for soil building and can only be effected if an increase in the organic matter is secured. If this can be accomplished other effects, physical and chemical, will follow.

The present position demands firstly that the rot which is at present occurring in many areas should be stopped and that at the same time strenuous attempts be made to build up sound agricultural practices. The marriage of animal husbandry with crop production must be achieved in all areas where the conditions are suitable and where they are not, crop production must proceed along lines which conform with the dictates of Nature.

In the Netherland Indies, the planned utilization of land has long been the basic policy of the Government and it has long been recognised that agricultural practices should conform to the needs of the land.

It should be our endeavour to foster in every way possible and in the widest circles this thought for the land. Erosion can be controlled if Nature is carefully studied and her secrets ascertained. The land is the chief asset of the tropical peoples and the proper use of that asset by present generations combined with its conservation for those to follow should be the primary aim of all.

Exploitation of soil fertility has gone far enough in many areas, whilst in others it has gone too far. A full stock of the position is now being undertaken and it is to be hoped that all who can will add their quota to the endeavour necessary to improve matters.

WEST INDIAN NOTES.

(Compiled by the Advisory Department, Imperial College of Tropical Agriculture.)

The Sugar Industry.

A drought equal in severity or even more severe than any on record within the last half century was experienced in 1939 in the Leeward Islands and Barbados. The effect of this drought has naturally been very marked on the sugar cane crop. But by reason of the application of knowledge gained in recent years from scientific investigation, resulting among other things in the adoption of improved methods of cultivation and the more correct use of artificial manures, and in the introduction of higher yielding varieties and the better allocation of varieties to soil types, the decline in production will not be so great as in former years of equally severe drought. Production in 1940 is estimated at about 28,000 tons sugar in St. Kitts, about 25 per cent. less than last year, and at 12,000 tons in Antigua or about half an average crop in that Island. In Barbados the estimate is 108,000 tons compared with a production of 159,000 tons in 1939. A year of subnormal rainfall favours high yields in St. Lucia and the estimate of 9,800 tons shows a marked increase on previous years. In Trinidad, where damage caused by froghopper has been unusually severe, production is estimated at 110,000 tons.

The Sea Island Cotton Industry.

The fourth ordinary general meeting of the West Indian Sea Island Cotton Association (Incorporated) was held in Antigua in November, 1939. Representatives attended from all the Island Cotton Associations with the exception of the Barbados Cotton Growers Association whose representation was effected by substitute. The Cotton Adviser to the Commissioner of Agriculture, who is an honorary member of the Association, was also present.

Reference is made in the following paragraphs to the more important matters considered at the meeting and to the more important decisions made by the Association.

Reports on the work of the previous year were presented by the Board of Directors and by the Advisory Committee in England. The former indicated that actual production in 1939 was slightly in excess of the total quantity recommended for production by the Association. The Directors' report also referred as usual to the activities of the Association in the West Indies which included the maintenance of advertisement booths in Barbados and Trinidad, the transmittal of market information to the Island Cotton Associations and the financial support given by the Association to the cotton breeding station in Montserrat. Mention was also made of the conclusion of the Cotton Pests Investigation which had been conducted by Mr. F. A. Squire for a period of three years. The report of the Advisory Committee indicated that the more important matters which engaged the attention of the Committee during the year were the administration of the trade mark, the investigation of cases of misrepresentation of Sea Island cotton goods, the use of Sea Island cotton for parachutes and balloon fabrics, and matters relating to publicity and to market competition of American grown Sea Island cotton.

The statistical position of the industry was reviewed together with the probable market requirements and, acting on the advice of the Advisory Committee, the Association recommended production of a crop of about 2,200,000 lb. of lint allocated to the various Islands in the manner shown in Table I.

Table I.

Island.	Production in 1940.	
The Montserrat Strain.		
Anguilla	30,000 lb.	
Antigua	330,000 ,,	
Montserrat ...	600,000 ,,	
Nevis	325,000 ,,	
St. Kitts	400,000 ,,	
British Virgin Islands	15,000 ,,	
		1,700,000 lb.
The Superfine Strain.		
Barbados	10,000 lb.	
St. Vincent ...	650,000 ,,	
		660,000 lb.
Total ...		2,360,000 lb.

The final reports submitted by Mr. Squire, the Entomologist appointed for the Cotton Pests Investigation, were examined and careful consideration was given to the question of pest control. The President stressed the value and importance to the cotton industry in the West Indies of the information which had been made available as a result of the investigation and expressed the hope that the Island Associations would make every possible effort to ensure that there was no relaxation in the strict application of Mr. Squire's recommendations.

The more important measures advocated by the meeting for adoption in the Islands in connexion with pest control are summarised as follows: the early introduction of regulations for ensuring the application of effective sanitation measures in ginneries and cotton storehouses; the disposal of all saleable cotton on hand at the end of the cotton season each year with the object of removing a possible source of early re-infestation of the new crop; and the strict enforcement of an annual close season of not less than three months in duration. The meeting took note of the unusually severe infestation of

cotton leaf defoliators in Antigua and Nevis in the last quarter of 1939 and recommended Island Associations to ensure that adequate stocks of insecticide and sprayers were kept in their respective Islands.

Mr. J. B. Hutchinson, Cotton Adviser, addressed the meeting on the subject of the quality of West Indian Sea Island cotton and reviewed the investigations which had been undertaken during the year in this respect under three heads, namely (i) tests of Island crops to determine the range of variation from year to year and Island to Island in the same strain, (ii) the study of the effects of soil and weather conditions on quality, and (iii) the study of the effect of breeding policy on quality.

The Banana Industry.

The number of Gros Michel bananas sold in 1938 and 1939 to the Canadian Banana Company from the Islands of the Eastern Group of the British West Indies is set forth in Table II.

Owing to the institution of a more rigid system of selection demanding better quality fruit, the number of stems accepted by the purchasing Company in 1939 was considerably less than in 1938.

Brevities.

Mr. C. C. Skeete, Acting Commissioner of Agriculture, returned to Trinidad from vacation leave on 11th October, 1939.

The Cotton Pests Investigation was concluded in September, 1939. Full reports have been submitted to the West Indian Sea Island Cotton Association (Incorporated) and to the Governments concerned. Mr. F. A. Squire, the Entomologist, has been transferred to an appointment in Sierra Leone.

* * *

The Acting Commissioner of Agriculture paid short visits to St. Vincent and St. Lucia in November and December, 1939, and attended the fourth ordinary general meeting of the West Indian Sea Island Cotton Association (Incorporated) in Antigua at the end of November, 1939.

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Mr. J. B. Hutchinson, Cotton Adviser to the Commissioner of Agriculture, visited Antigua at the end of November to attend the meeting of the West Indian Sea Island Cotton Association (Incorporated).

* * *

Mr. P. E. Turner, Adviser on Sugar Cane Experiments to the Commissioner of Agriculture, visited St. Kitts and Antigua from 25th November to 21st December, 1939.

TABLE II.

Statement of Number of Stems of Bananas sold to the Canadian Banana Company and exported from the Islands in the Eastern Group during 1938 and 1939.

	Trinidad.		Grenada.		St. Vincent.		St. Lucia.		Dominica.		Total.	
	1938	1939	1938	1939	1938	1939	1938	1939	1938	1939	1938	1939
Nines ...	45,418	24,681	59,517	47,086	13,547	7,827	40,441	18,902	29,714	10,101	188,637	108,597
Eights ...	26,476	21,388	27,988	27,080	14,292	11,220	38,412	21,856	22,136	12,560	129,304	94,104
Sevens ...	11,162	20,528	18,800	30,026	14,628	18,368	16,948	31,532	13,780	14,254	75,318	114,708
Sixes ...	—	—	—	4,068	—	1,972	—	1,144	—	1,180	—	8,364
Total stems exported	83,056	66,597	106,305	108,260	42,467	39,387	95,801	73,434	65,630	38,095	393,259	325,773
Equivalent counts ...	70,856	50,886	89,908	83,446	31,580	25,919	77,724	51,346	53,208	26,948	323,276	238,545
Percentage counts ...	85	76	84	77	74	66	81	70	81	71	82	73
Stems purchased but not shipped	48,672	—	29,976	200	32,804	—	53,149	—	61,445	2,030	226,046	2,230
Total stems purchased	131,728	66,597	136,281	108,460	75,271	39,387	148,950	73,434	127,075	40,125	619,305	328,003

CULTIVATION AND DISTILLATION OF LEMON GRASS IN TRAVANCORE.

The cultivation of lemon grass in India is now restricted to remote country districts in the northern portion of the Travancore State, where the elevation ranges from sea level to about 500 feet.

Lemon grass is a hardy plant and will grow in almost any kind of soil from rich loam to laterite. The type of soil does, however, affect the oil content of the grass. The more fertile the soil the lower the citral content, although the yield is high. In laterite soil the citral content is high, but the yield is naturally less.

Even in areas where the grass receives some attention the growth is very scattered. Patches of land here and there may be quite bare and elsewhere there will be a prolific growth.

The root is perennial and an area once planted will continue bearing for some years with little or no attention. The life varies from six years in some districts to fifteen years in others, but the majority of reports indicate that 8-10 years is the normal productive life of the grass, the most productive period being from the second till the sixth year of growth.

When ready for cutting the grass is about 4 feet high. The part which contains the oil is the round stalk at the foot of each blade in the heart of the clump. This portion varies in length from 6 inches to 1 foot.

It is found that it is bad to cut during or soon after rain. The oil mounts highest during the dry weather and it is then therefore that the best results are obtained. A continuously wet season therefore would considerably affect the yield of oil.

Sowing commences as soon as there has been sufficient rain to moisten the soil well. The ground, which only requires to be cleared of scrub and roughly ploughed, is usually prepared in advance during the dry weather. Normally, the first showers are about the second half of March and this can be taken as the sowing period. Although the actual time of sowing may differ each year according to weather conditions, the variation is not great.

Provided weather conditions continue normal, neither too much nor too little rain and plenty of sunshine, the young grass will be ready for cutting after about six or seven weeks. Areas which are already in grass will be ready for cutting much sooner. The harvesting season may be taken therefore as May/December. There are normally only four cuttings during this period, about six or seven weeks apart.

After cutting, the grass is taken for distilling. A big factory with up-to-date modern equipment and elaborate machinery is not necessary for the extraction of lemon grass oil. The scene of operations is a small thatched shed measuring 20 feet × 16 feet. At one end of the shed a big cylindrical vessel about 5 feet high and about 12 feet in circumference rests on a crude country hearth. Thence a pipe projects horizontally, discharging into a coiled pipe fitted into a tub containing cold water. At the outlet of the coiled pipe, another small vessel is placed to receive the contents discharged. At one side of the big vessel there is a manhole into which small bundles of grass are deposited. For one distillation about 250 to 300 bundles are put into the vessel, together with sufficient water, and the opening is then firmly closed. The hearth is then made ablaze and gradually the process of distillation commences. The oil passes off as vapour, becomes condensed in its passage through the pipe and gets discharged into the small vessel. It is necessary that the tub should be frequently filled with cold water in order to effect condensation. The discharged matter in the small vessel will be a mixture of lemon grass oil at the top and a good quantity of water at the bottom. A syphon tube arrangement fixed to the collecting vessel facilitates the discharge of the watery matter, leaving the oil behind.

The price of lemon grass oil in 1934 rose to as much as 4*s.* 6*d.* per lb. *c.i.f.* London, and since 1936 the highest and lowest prices touched have been 2*s.* 3*d.* and 1*s.* 3½*d.* respectively; during the greater part of the period 1936 to date the price has ruled below 1*s.* 6*d.* and at the end of August 1939 business was done at 1*s.* 4½*d.* *c.i.f.*—(*Bulletin of the Imperial Institute*, Vol. XXXVII, No. 3, pp. 365-67, 1939.)

AGRICULTURAL PRODUCTS AS INSECTICIDES.*

About 100 million dollars' worth of insecticides and fungicides are employed annually against insect and fungous pests causing an annual loss of three billion dollars in the United States. Although the materials now largely used for this purpose (compounds of arsenic, fluorine, lead, copper and sulphur) are of mineral origin, vegetable products are being used to an increasing extent. This is because many organic compounds are more toxic to insects but less toxic to man than are lead arsenate and other inorganic poisons. In addition to organic insecticides that exist naturally in plants, such as nicotine, anabasine, the pyrethrins, rotenone, ground-nut oil and other plant oils, products derived from coniferous trees, such as pine-tar oil, are also valuable insecticides, and synthetic compounds derived from oils, alcohols, furfural and other promising plant products are now coming into commerical use as insecticides. It is conjectured that in the future insecticides will be mostly organic compounds obtained from plants now regarded as worthless weeds or synthesised from products of plant origin. The possibilities of constructive chemical research in this field are boundless and should result in numerous products of great economic value.

* By R. C. Roark. *Industr. Engng. Chem.* 31, pp. 168-171, 4 figs., 5 refs, Easton, Pa, 1939. Reprinted from *Rev. of Applied Ent.* Ser. A, Vol. 27. Part II, p. 593, 1939.

CHEMICAL NOTES.

(Compiled by the College Department of Chemistry and Soil Science.)

The Laboratory Determination of Soil Fertility.*

Doubtless the method of fertility plots must remain the ultimate procedure by which the precise fertilizer requirements of a particular soil type, under a given set of climatic and other factors may be determined; but the method is time-consuming and laborious. Any chemical method of approach is purely empirical in character even though based on a sound scientific foundation; and laboratory tests must of necessity be checked and tried against adequate field experiments to establish their reliability.

Some ten years ago complete plans were laid for a programme of field trials and parallel laboratory tests, to be conducted on selected soil types in each of the major cane-growing areas of Queensland. The trial plan adopted was the 5 × 5 Latin square layout, embracing the treatments NPK, NP, NK, PK, and *Check* or "no manure" plots. The crop increases due to the three plant foods were then obtainable by subtracting the mean yields for PK, NK, and NP, respectively, from the mean yield of the fully-fertilized plots.

At the same time as the fertility trial was set out, a soil sample was taken from each of the plots receiving no manure, by taking six auger borings from the soil to plough depth; these were composited to provide what could reasonably be regarded as an average sample of the surface soil of the experimental area. This was analysed for "available" phosphate and potash.

Available Phosphate Test: 2.5 grms. of air-dried soil and 500 ml. N/100 H_2SO_4 were agitated for a period of 16 hours, and the suspension filtered through a specially constructed Buchner funnel system for ultra-filtration, which provided a perfectly clear filtrate. An aliquot of the filtrate (usually 95 ml.) was taken, and the P_2O_5 content determined colorimetrically by the Truog-Meyer modification of the Denigès method.

Potash Test: It would appear that the "availability" of the replaceable potash present in the soil will be a function of both the total amount present and the proportion of total replaceable cations including H+.

In determining the replaceable K+, 25 to 50 grms. of the soil were leached (in a special funnel) with N/50 HCl, the leachate evaporated to dryness, the residue treated with nitric acid to destroy organic matter, and with HCl to render the silica insoluble, and finally extracted with dilute HCl and filtered. Then platinic chloride was added, and the determination completed in the usual manner.

Conclusions.—Summarizing the available phosphate results as a whole, of the 122 comparisons, the following correlations between laboratory tests and field experience were obtained: positive, 102 cases; negative, 15; and doubtful, 5. It will be agreed that such a high degree of concordance was substantially better than one might reasonably anticipate, allowing for the empirical character of the chemical test, and the complete disregard of any factors such as soil type or climatic influences.

In the potash trials, with 97 individual comparisons between field trials and chemical tests, the correlations were as follows: positive, 79; negative, 16; and doubtful, 2. Hence, the concordance between laboratory test and field response was not so high as was the case for the phosphate test, doubtless due in a large measure to the arbitrary nature and approximate character of the criterion on which the assessment was based.—(*Int. Sug. Jr.* Vol. XLI, No. 492, 1939.)

* H. W. Kerr and C. R. von Stieglitz. Technical Communication No. 9 (1938); Bureau of Sugar Experiment Stations, Brisbane.

* * *

Soil Problems in the Tropics.

In the editorial article entitled "White Settlement in the Tropics" of *Nature*, 29th July, 1939, reference was made to the insistence in the report of the Commission appointed to inquire into the possibilities of white settlement in British Guiana of the "inherent poverty of many, perhaps most, tropicals soils" in contrast to earlier beliefs in their inexhaustible fertility. Writing from the East African Research Station, Amani, Mr. G. Milne foresees a danger that facile generalizations regarding tropical soils as such may result. He points out that "tropical soils tend to be poor when the climate is very wet, when the soils are of advanced maturity, when (like any other soils) they have suffered from man-accelerated erosion, or when their parent materials have been exhausted of plant nutrients by previous geological processes". One or more of these factors has rendered huge areas of East Africa infertile, but there are still large tracts where pessimism on grounds of intrinsic soil infertility alone is not justified. Recent work has made it clear that neither the luxuriance of natural rain-forest cover nor of grassland vegetation affords a reliable guide to the agricultural value of soils (Hardy, F. *Trop. Agriculture*, 13, 315; 1936: Walter, H., *Forstliche Wochenschrift Silva*, 22, 201; 1936: Milne, G., *East African Agric. J.* July 1937), and that therefore an ecological survey cannot take the place of a soil survey. The fundamental principle seems to be that a high forest has matured along with the soil that nourished it; in the old age of both, the forest comes to depend very little on further material supplies from a highly leached and impoverished soil. Two things seem clear: one that the principles of good soil management in the tropics have yet to be fully understood, the other that tropical soils are liable under improper management to deteriorate at a rate almost unknown in temperate latitudes. A single rainy season can completely destroy the fertility of a tropical soil unwisely exposed.—(*Nature*, Vol. 144, No. 3656, p. 892 and 901, 1939.)